CLAIMS

1.   A method of transmitting data from a transmitting entity to a receiving entity in a wireless multi-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

processing a data packet to obtain a block of data symbols;

demultiplexing pilot symbols and the block of data symbols onto a plurality of subbands to obtain, for the data packet, a plurality of sequences of pilot and data symbols for the plurality of subbands; and

performing spatial processing on the sequence of pilot and data symbols for each subband with at least one steering vector selected for the subband, the spatial processing randomizing a plurality of effective single-input single-output (SISO) channels observed by the plurality of sequences of pilot and data symbols sent on the plurality of subbands.

2.   The method of claim 1, wherein the sequence of pilot and data symbols for each subband is spatially processed with one steering vector selected for the subband.

3.   The method of claim 2, wherein a plurality of different steering vectors are used for the plurality of subbands.

4.   The method of claim 2, wherein the one steering vector used for spatial processing for each subband is unknown to the receiving entity.

5.   The method of claim 1, wherein the sequence of pilot and data symbols for each subband is spatially processed with at least two steering vectors selected for the subband.

6.   The method of claim 1, wherein one pilot or data symbol is sent on each subband in each symbol period, and wherein the sequence of pilot and data symbols for each subband is spatially processed with a different steering vector for each symbol period.

7.   The method of claim 1, wherein the at least one steering vector used for spatial processing for each subband is known only to the transmitting entity and the receiving entity.

8.   The method of claim 1, wherein the spatial processing with the at least one steering vector for each subband is performed only on data symbols.

9.   The method of claim 1, wherein the processing a data packet includes

encoding the data packet in accordance with a coding scheme to obtain coded data,

interleaving the coded data to obtain interleaved data, and

symbol mapping the interleaved data in accordance with a modulation scheme to obtain the block of data symbols.

10.   The method of claim 1, further comprising:

selecting the at least one steering vector for each subband from among a set of L steering vectors, where L is an integer greater than one.

11.   The method of claim 10, wherein the L steering vectors are such that any pair of steering vectors among the L steering vectors have low correlation.

12.   The method of claim 6, further comprising:

selecting a steering vector for each subband in each symbol period from among a set of L steering vectors, where L is an integer greater than one.

13.   The method of claim 1, wherein each steering vector includes T elements having same magnitude but different phases, where T is the number of transmit antennas at the transmitting entity and is an integer greater than one.

14.   An apparatus in a wireless multi-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

a data processor operative to process a data packet to obtain a block of data symbols;

a demultiplexer operative to demultiplex pilot symbols and the block of data symbols onto a plurality of subbands to obtain, for the data packet, a plurality of sequences of pilot and data symbols for the plurality of subbands; and

a spatial processor operative to perform spatial processing on the sequence of pilot and data symbols for each subband with at least one steering vector selected for the subband, the spatial processing randomizing a plurality of effective single-input single-output (SISO) channels observed by the plurality of sequences of pilot and data symbols sent on the plurality of subbands.

15.   The apparatus of claim 14, wherein the spatial processor is operative to spatially process the sequence of pilot and data symbols for each subband with one steering vector selected for the subband.

16.   The apparatus of claim 14, wherein the spatial processor is operative to spatially process the sequence of pilot and data symbols for each subband with at least two steering vectors selected for the subband.

17.   The apparatus of claim 16, wherein the at least two steering vectors for each subband are known only to a transmitting entity and a receiving entity for the data packet.

18.   The apparatus of claim 14, wherein each steering vector includes T elements having same magnitude but different phases, where T is the number of antennas used to transmit the data packet and is an integer greater than one.

19.   An apparatus in a wireless multi-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

means for processing a data packet to obtain a block of data symbols;

means for demultiplexing pilot symbols and the block of data symbols onto a plurality of subbands to obtain, for the data packet, a plurality of sequences of pilot and data symbols for the plurality of subbands; and

means for performing spatial processing on the sequence of pilot and data symbols for each subband with at least one steering vector selected for the subband, the spatial processing randomizing a plurality of effective single-input single-output (SISO) channels observed by the plurality of sequences of pilot and data symbols sent on the plurality of subbands.

20.   The apparatus of claim 19, wherein the sequence of pilot and data symbols for each subband is spatially processed with one steering vector selected for the subband.

21.   The apparatus of claim 19, wherein the sequence of pilot and data symbols for each subband is spatially processed with at least two steering vectors selected for the subband.

22.   The apparatus of claim 21, wherein the at least two steering vectors for each subband are known only to a transmitting entity and a receiving entity for the data packet.

23.   The apparatus of claim 19, wherein each steering vector includes T elements having same magnitude but different phases, where T is the number of antennas used to transmit the data packet and is an integer greater than one.

24.   A method of transmitting data from a transmitting entity to a receiving entity in a wireless multiple-input multiple-output (MIMO) communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

processing a data packet to obtain a block of data symbols;

demultiplexing pilot symbols and the block of data symbols onto a plurality of subbands; and

performing spatial processing on the pilot and data symbols for each subband with at least one steering matrix selected for the subband, the spatial processing randomizing a plurality of effective MIMO channels for the plurality of subbands observed by the pilot and data symbols sent on the plurality of subbands.

25.   The method of claim 24, wherein the pilot and data symbols for each subband are spatially processed with one steering matrix selected for the subband.

26.   The method of claim 25, wherein the one steering matrix used for spatial processing for each subband is unknown to the receiving entity.

27.   The method of claim 24, wherein the pilot and data symbols for each subband are spatially processed with a different steering matrix for each symbol period.

28.   The method of claim 24, wherein the at least one steering matrix used for spatial processing for each subband is known only to the transmitting entity and the receiving entity.

29.   The method of claim 24, wherein the spatial processing with the at least one steering matrix for each subband is performed only on data symbols.

30.   The method of claim 24, further comprising:

multiplying spread symbols for each subband, obtained from the spatial processing with the at least one steering matrix, to transmit the spread symbols on eigenmodes of the MIMO channel for the subband.

31.   The method of claim 24, further comprising:

selecting the at least one steering matrix for each subband from among a set of L steering matrices, where L is an integer greater than one.

32.   The method of claim 27, further comprising:

selecting a steering matrix for each subband in each symbol period from among a set of L steering matrices, where L is an integer greater than one.

33.   The method of claim 31, wherein the L steering matrices in the set are such that any pair of steering matrices among the L steering matrices have low correlation.

34.   An apparatus in a wireless multiple-input multiple-output (MIMO) communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

a data processor operative to process a data packet to obtain a block of data symbols;

a demultiplexer operative to demultiplex pilot symbols and the block of data symbols onto a plurality of subbands; and

a spatial processor operative to perform spatial processing on the pilot and data symbols for each subband with at least one steering matrix selected for the subband, the spatial processing randomizing a plurality of effective MIMO channels for the plurality of subbands observed by the pilot and data symbols sent on the plurality of subbands.

35.   A method of transmitting data from a transmitting entity to a receiving entity in a wireless multi-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

transmitting data to the receiving entity using a first mode if channel response estimates for the receiving entity are unavailable to the transmitting entity, wherein data symbols are spatially processed with pseudo-random steering vectors or matrices in the first mode; and

transmitting data to the receiving entity using a second mode if the channel response estimates for the receiving entity are available to the transmitting entity, wherein data symbols are spatially processed with steering vectors or matrices derived from the channel response estimates in the second mode.

36.   The method of claim 35, wherein the transmitting data to the receiving entity using a first mode includes

processing a first data packet to obtain a first block of data symbols,

demultiplexing pilot symbols and the first block of data symbols onto a plurality of subbands, and

performing spatial processing on the pilot and data symbols for each subband with at least one pseudo-random steering vector selected for the subband, the spatial processing randomizing a plurality of effective single-input single-output (SISO) channels observed by the pilot and data symbols sent on the plurality of subbands.

37.   The method of claim 36, wherein the transmitting data to the receiving entity using a second mode includes

processing a second data packet to obtain a second block of data symbols,

demultiplexing pilot symbols and the second block of data symbols onto the plurality of subbands, and

performing spatial processing on the pilot and data symbols for each subband with a steering vector, derived from a channel response estimate for a multiple-input single-output (MISO) channel for the subband, to steer transmission of the pilot and data symbols toward the receiving entity.

38.   The method of claim 35, wherein the transmitting data to the receiving entity using a first mode includes

processing a first data packet to obtain a first block of data symbols;

demultiplexing pilot symbols and the first block of data symbols onto a plurality of subbands; and

performing spatial processing on the pilot and data symbols for each subband with at least one pseudo-random steering matrix selected for the subband, the spatial processing randomizing a plurality of effective multiple-input multiple-output (MIMO) channels for the plurality of subbands observed by the pilot and data symbols sent on the plurality of subbands.

39.   The method of claim 38, wherein the transmitting data to the receiving entity using a second mode includes

processing a second data packet to obtain a second block of data symbols,

demultiplexing pilot symbols and the second block of data symbols onto the plurality of subbands, and

performing spatial processing on the pilot and data symbols for each subband with a steering matrix, derived from a channel response estimate for a MIMO channel for the subband, to transmit the pilot and data symbols on eigenmodes of the MIMO channel for the subband.

40.　　An apparatus in a wireless multi-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

a controller operative to select a first mode for data transmission to a receiving entity if channel response estimates for the receiving entity are unavailable and select a second mode for data transmission to the receiving entity if the channel response estimates are available, wherein data symbols are spatially processed with pseudo-random steering vectors in the first mode and with steering vectors derived from the channel response estimates in the second mode; and

a spatial processor operative to perform spatial processing for each block of data symbols in accordance with the mode selected for the block.

41.　　A method of receiving a data transmission sent by a transmitting entity to a receiving entity in a wireless multiple-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

obtaining, via a single receive antenna, S sequences of received symbols for S sequences of pilot and data symbols transmitted via S subbands by the transmitting entity, where S is an integer greater than one, and wherein the S sequences of pilot and data symbols are spatially processed with a plurality of steering vectors at the transmitting entity to randomize S effective single-input single-output (SISO) channels observed by the S sequences of pilot and data symbols;

deriving channel response estimates for the S effective SISO channels based on received pilot symbols in the S sequences of received symbols; and

performing detection on received data symbols in the S sequences of received symbols based on the channel response estimates for the S effective SISO channels to obtain detected symbols.

42.　　The method of claim 41, wherein the sequence of pilot and data symbols for each subband is spatially processed at the transmitting entity with one steering vector selected for the subband.

43.　　The method of claim 42, wherein the one steering vector used for spatial processing for each subband is unknown to the receiving entity.

44. The method of claim 41, wherein the sequence of pilot and data symbols for each subband is spatially processed at the transmitting entity with at least two steering vectors selected for the subband.

45. The method of claim 44, wherein the at least two steering vectors used for spatial processing for each subband are known only to the transmitting entity and the receiving entity.

46. A receiver apparatus in a wireless multiple-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

a demodulator operative to provide S sequences of received symbols, obtained via a single received antenna, for S sequences of pilot and data symbols transmitted via S subbands by a transmitting entity, where S is an integer greater than one, and wherein the S sequences of pilot and data symbols are spatially processed with a plurality of steering vectors at the transmitting entity to randomize S effective single-input single-output (SISO) channels observed by the S sequences of pilot and data symbols;

a channel estimator operative to derive channel response estimates for the S effective SISO channels based on received pilot symbols in the S sequences of received symbols; and

a detector operative to perform detection on received data symbols in the S sequences of received symbols based on the channel response estimates for the S effective SISO channels to obtain detected symbols.

47. The apparatus of claim 46, wherein the sequence of pilot and data symbols for each subband is spatially processed at the transmitting entity with one steering vector selected for the subband.

48. The apparatus of claim 46, wherein the sequence of pilot and data symbols for each subband is spatially processed at the transmitting entity with at least two steering vectors selected for the subband.

49.   The apparatus of claim 48, wherein the at least two steering vectors used for spatial processing for each subband are known only to the transmitting entity and a receiving entity for the data packet.

50.   A receiver apparatus in a wireless multiple-antenna communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

means for obtaining, via a single receive antenna, S sequences of received symbols for S sequences of pilot and data symbols transmitted via S subbands by a transmitting entity, where S is an integer greater than one, and wherein the S sequences of pilot and data symbols are spatially processed with a plurality of steering vectors at the transmitting entity to randomize S effective single-input single-output (SISO) channels observed by the S sequences of pilot and data symbols;

means for deriving channel response estimates for the S effective SISO channels based on received pilot symbols in the S sequences of received symbols; and

means for performing detection on received data symbols in the S sequences of received symbols based on the channel response estimates for the S effective SISO channels to obtain detected symbols.

51.   The apparatus of claim 50, wherein the sequence of pilot and data symbols for each subband is spatially processed at the transmitting entity with one steering vector selected for the subband.

52.   The apparatus of claim 50, wherein the sequence of pilot and data symbols for each subband is spatially processed at the transmitting entity with at least two steering vectors selected for the subband.

53.   The apparatus of claim 52, wherein the at least two steering vectors used for spatial processing for each subband are known only to the transmitting entity and a receiving entity for the data packet.

54.   A method of receiving a data transmission sent by a transmitting entity to a receiving entity in a wireless multiple-input multiple-output (MIMO) communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

obtaining, via R receive antennas at the receiving entity, S sets of R sequences of received symbols for S sets of T sequences of pilot and data symbols transmitted on S subbands of T transmit antennas by the transmitting entity, one set of R sequences of received symbols and one set of T sequences of pilot and data symbols for each subband, where R, S, and T are integers greater than one, and wherein the set of T sequences of pilot and data symbols for each subband is spatially processed with at least one steering matrix at the transmitting entity to randomize an effective MIMO channel observed by the set of T sequences of pilot and data symbols;

deriving a channel response estimate for the effective MIMO channel for each subband based on received pilot symbols in the S sets of R sequences of received symbols; and

performing receiver spatial processing on received data symbols in the set of R sequences of received symbols for each subband with the channel response estimate for the effective MIMO channel for the subband to obtain detected symbols for the subband.

55.   The method of claim 54, wherein the receiver spatial processing is based on a channel correlation matrix inversion (CCMI) technique.

56.   The method of claim 54, wherein the receiver spatial processing is based on a minimum mean square error (MMSE) technique.

57.   The method of claim 54, wherein the set of T sequences of pilot and data symbols for each subband is spatially processed at the transmitting entity with one steering matrix selected for the subband.

58.   The method of claim 57, wherein the one steering matrix used for spatial processing for each subband is unknown to the receiving entity.

59.   The method of claim 54, wherein the set of T sequences of pilot and data symbols for each subband is spatially processed at the transmitting entity with at least two steering matrices selected for the subband.

60. The method of claim 59, wherein the at least two steering matrices used for spatial processing for each subband are known only to the transmitting entity and the receiving entity.

61. A receiver apparatus in a wireless multiple-input multiple-output (MIMO) communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

a plurality of (R) demodulators operative to provide received pilot symbols and received data symbols obtained for R receive antennas, wherein S sets of R sequences of received symbols are obtained, via the R receive antennas, for S sets of T sequences of pilot and data symbols transmitted on S subbands of T transmit antennas by a transmitting entity, one set of R sequences of received symbols and one set of T sequences of pilot and data symbols for each subband, where R, S, and T are integers greater than one, and wherein the set of T sequences of pilot and data symbols for each subband is spatially processed with at least one steering matrix at the transmitting entity to randomize an effective MIMO channel observed by the set of T sequences of pilot and data symbols;

a channel estimator operative to derive a channel response estimate for an effective MIMO channel for each subband based on the received pilot symbols and steering matrices used for data transmission by the transmitting entity; and

a spatial processor operative to perform receiver spatial processing on received data symbols for each subband based on the channel response estimate for the effective MIMO channel for the subband to obtain detected symbols for the subband.

62. A receiver apparatus in a wireless multiple-input multiple-output (MIMO) communication system utilizing orthogonal frequency division multiplexing (OFDM), comprising:

means for obtaining, via R receive antennas, S sets of R sequences of received symbols for S sets of T sequences of pilot and data symbols transmitted on S subbands of T transmit antennas by a transmitting entity, one set of R sequences of received symbols and one set of T sequences of pilot and data symbols for each subband, where R, S, and T are integers greater than one, and wherein the set of T sequences of pilot and data symbols for each subband is spatially processed with at least one steering

matrix at the transmitting entity to randomize an effective MIMO channel observed by the set of T sequences of pilot and data symbols;

means for deriving a channel response estimate for the effective MIMO channel for each subband based on received pilot symbols in the S sets of R sequences of received symbols; and

means for performing receiver spatial processing on received data symbols in the set of R sequences of received symbols for each subband with the channel response estimate for the effective MIMO channel for the subband to obtain detected symbols for the subband.